

Computerized Cognitive Assessment System for Dementia Screening Application

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Abstract

The occurrence of dementia is increasing in an aging, even aged society. According to the previous research reports, early diagnosis and treatment of dementia may slow down the progression of illness and reduce the cost of care-giving. There are several assessment measures currently applied in clinics, such as Mini-Mental State Examination (MMSE), Clinical Dementia Rating (CDR), Cognitive Abilities Screening Instrument (CASI), Montreal Cognitive Assessment (MoCA), etc. However, their common feature is the need of instructors to guide one patient at a time. In addition, most of the tests are based on western culture. In Taiwan area, the hospital visiting rate of dementia patients is very low. This points out the problem that the clinical assessments are not often used for screening. In this study, a game based computerized measure for assisting the assessment of the suspected subjects is developed and its efficacy is discussed. The proposed system is developed and embedded in an interactive game based on Taiwanese culture theme. This system can work on Android and Windows platform, and it includes obtaining the user background and testing different cognitive domains, including attention, language, memory, visuospatial abilities, executive function and orientation.

Keywords

Dementia screening • Computerized • Cognitive assessment • Game

1 Introduction

1.1 Background

Dementia is shown to be an age-related disease and becomes an important issue among elderly population. According to the world Alzheimer report in 2015, it is revealed that the rapid growing of population with dementia is about 46.8 million, and in average, there will be one more dementia case every 3 s [1].

In 2015, the global cost of care for dementia is about 818 billion dollars [1]. This is due to the increases in numbers of people with dementia and in per person cost [2]. From a statistical estimation of previous study, the costs for moderate dementia patients were 1.4 times compared to the cost for mild dementia. Furthermore, for severe dementia, it is doubled [3]. This implies that the total cost increases significantly by the disease severity. Early detection and diagnosis of dementia offers a number of benefits that health care providers can deliver better care to help affected cases and their family, further more improve those reversible cognitive impairment condition.

However, according to the population report provided by National Development Council, Taiwan [4], about 73% of dementia patients are not diagnosed and treated. It shows the early detection of dementia among people with an easy assessment measure is needed and important.

1.2 Cognitive Assessments

General clinical assessments such as Mini-Mental State Examination (MMSE) [5], Cognitive Abilities Screening Instrument (CASI) [6] and Montreal Cognitive Assessment (MoCA) [7] and so on, have been often used.

MMSE and MoCA have different criteria to set cut-off points for different years or education and age. CASI even concerns the sex as scoring criteria, for example, cut-off

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point is 63 for male who is under 79 years old and didn't receive education, but for female, it is 49. They are usually applied with paper format and administrated by professional psychologists.

A comparison for these assessments is listed in Table 1. Although these tests are validated clinically, they are not easily employed for general use without appropriate knowledge.

1.3 Computerization

Personal computer and mobile device applications have been developed for psychology evaluation recently. They are able to enhance clinical judgment, reduce testing time, improve ecological validity, optimize models for treatment planning, and incorporate new assessment theories [8]. Computerized assessment is likely to enhance efficiency through rapid scoring, and novel presentation [9]. According to Finger et al., computer-administered results also have been found to have negligible differences in scores compared to paper-pencil method [10].

Though there are many advantages, computerization report should not replace the judgement from clinicians [9]. The proper application of computerized assessment will be the assistant tool for clinicians to judge or interpret [8].

1.4 Serious Game

Tong et al. compared the differences between the traditional paper-and-pencil cognitive assessments and serious games, the serious game can be administrate by non-clinicians and has the advantages of repeatability and more entertainment to motivate subjects to perform the test [11]. Sea Hero Quest is a mobile serious game designed to help early diagnosis for dementia [12]. However, to finish whole game needs much time. In addition, it focuses on memory and orientation measures, but not other domains.

As mentioned above, in this study we try to develop a mobile game which covers general cognitive domains, and design it with a friendly user interface. We hope it can be

applied as an assistive tool for clinical assessment, or help general people for self-assessment.

2 Materials and Methods

2.1 Computerized Cognitive Assessment System

The computerized cognitive assessment system (CCAS) is proposed and developed according to the general clinical cognitive assessments as previous mentioned. It includes obtaining the user basic information, and testing the orientation, attention, calculation, naming, language, memory, executive function and visuospatial abilities, as the main domains of the diagnosis criteria.

The game elements in the CCAS are based on Taiwanese culture. The user interface is designed with big pictures and buttons, and displays instructions with live leading speaking [13], to make it more friendly and easier for elder users and the subjects with illiterate to operate. As shown in Fig. 1, the form of CCAS is in mobile game, which is played on 13-in. touch screen in a well illuminated environment for the experiments.

In CCAS, we set the total score as 100 points. User will get a score and a corresponding suggestion in the end of the game. The points are divided into 3 levels: 80–100 describes that users' cognitive abilities are normal, 60–79 means users' cognitive abilities are not bad but they should try to exercise brain often, and under 59 is for those whose cognitive abilities probably have impairment or degradation and should receive treatment.

2.2 Subject Information

The ages of enrolled participants range from 50 to 95 years old. They are recruited from Tainan Hospital, Ministry of Health and Welfare with the written informed consent and IRB approved. Clinical Dementia Rating (CDR) [14] score is used to classify the participants into 3 groups. Normal Control (NC) includes the participants whose CDR score is

Table 1 Comparison of different clinical assessment

Test	Time	Administrator	Form	
MMSE	10–15 min	Yes	Paper-and-pencil	Health insurance payment condition in Taiwan; less sensitive to high educated patients
MoCA	10–25 min	Yes	Paper-and-pencil	More sensitive to MCI and interesting
CDR	15–20 min	Yes	Paper-and-pencil	Detailed for staging dementia severity
CASI	20–30 min	Yes	Paper-and-pencil	More assessment details on different domains
Sea Hero Quest	75 levels	No	Mobile game	An interesting game with vivid story; Need time to finish all levels

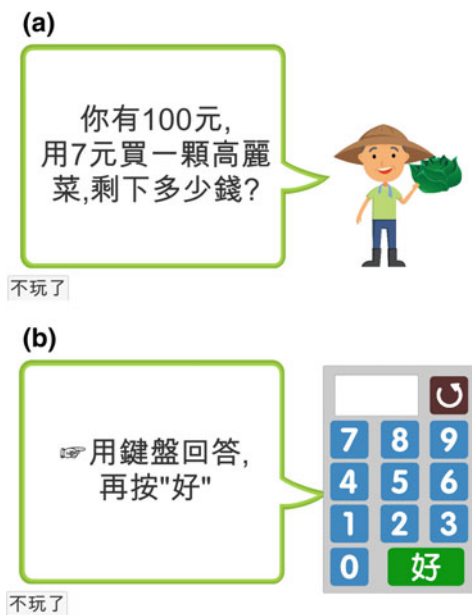


Fig. 1 An example of the game interface for testing attention and calculation ability. **a** Display the question with text and live speaking, and **b** guide the user to answer

0; Mild Cognitive Impairment (MCI) is CDR score is 0.5; Dementia is whose CDR score is 1–2. Exclusion criteria is the patient who has (1) significant listening or visual disability, (2) significant hand dysfunction, (3) the diagnosed mental illness, (4) the addiction to alcohol or medicine, and (5) CDR score equal to 3 or higher, those who obviously are unable to understand or follow the instructions.

All the 3 groups are asked to perform the standard cognitive assessment, including Mini-Mental State Examination (MMSE), Cognitive Abilities Screening Instrument (CASI), Montreal Cognitive Assessment (MoCA), Activity of Daily Living Inventory (ADL-I), and also to play the computerized cognitive assessment system (CCAS) that proposed and implemented in this study.

2.3 Experimental Design

The flowchart of experimental protocol is designed and depicted in Fig. 2. The pilot test is set to check the system primarily. Some part of interface design has been modified by the users' feedbacks. Then we conduct clinical trial including different assessment tools and a questionnaire about the system, to get at least 50 normal controls and 50 dementia cases, and all of them have to be confirmed by doctors. For the results we will calculate the cut-off score, reliability, validity, sensitivity of the system, and do correlation between the system and other tests. Finally, the statistical results are analyzed and discussed about its performance.

2.4 Questionnaire

In this study, a brief questionnaire is used to figure out whether the CCAS is acceptable to be applied for cognitive assessment. It includes questions about user background (sex, age, education etc.), whether it is easy for user to use tablet, how users feel interesting and familiarity to the game story, user experience of the interface design (typesetting, color, instruction etc.), and compared to other assessments whether the CCAS is more interesting, more clear to understand, and easier to operate on their own. The scale of each question is 5-point, the more points means the more user agrees with the statements.

3 Results and Discussion

3.1 Results

The pilot test results are shown in Table 2. We recruited 5 normal cases and 5 dementia cases whose age is ranged from 53 to 89 years old. The value under each cognitive abilities

Fig. 2 Flowchart of experiment

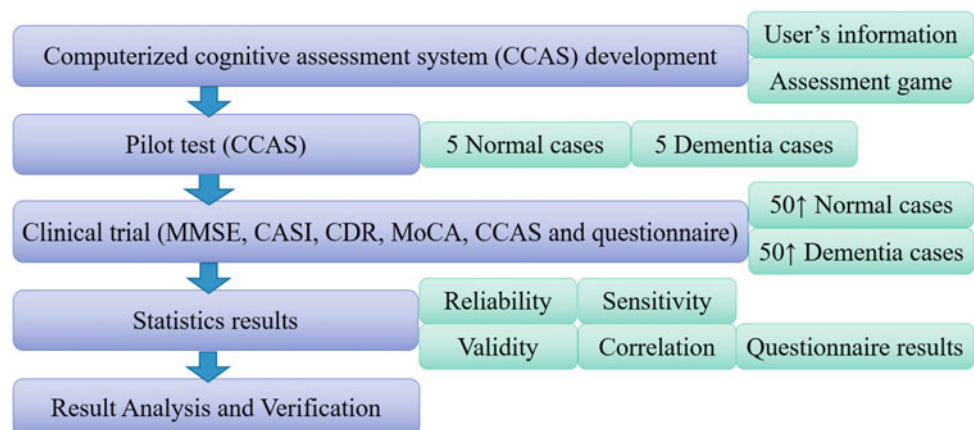


Table 2 Pilot test results

No.	Group	Age	Orientation	Attention	Calculation	Naming	Language	Verbal fluency	Visuospatial abilities	Memory
A	Normal	53	1	1	1	1	1	1	1	0.4
B	Normal	68	0.8	1	1	0.8	1	1	1	0.2
C	Normal	70	1	1	0.8	0.8	1	1	1	0.2
C	Normal	78	1	1	0.4	0.8	0.8	0.9	1	0.2
D	Normal	85	0.6	0	0.4	0.6	0.2	0.8	1	0
F	Dementia	68	0.6	1	1	0.7	1	1	1	0
G	Dementia	80	0.8	1	1	0.8	1	0.9	1	0.4
H	Dementia	83	0.2	0	0.6	0.6	0	0.8	0	0
I	Dementia	84	0	0	0	0.5	0.4	0.8	0	0
J	Dementia	89	0.2	0	0	0.6	0.2	0.7	0	0

is the correct rate, which is the ratio of the numbers of correct answers and total questions. More data will be reported during conference.

3.2 Discussion

The pilot test results are shown to have good correlation. The correct rate in dementia group is approximately lower than in normal group, and it is also age-relative. Case F and G show the noticed performance, it's probably because they are diagnosed as slight Alzheimer's disease, they may still keep cognitive ability. As to memory domain, the result seems not so significant, so we would modify the question and instruction. The current small data helps us to improve this system, and we expect the results from clinical trial would be more complete and reliable.

From subjects' experience feedback, it showed that they like this game and think it is interesting, the play-time is acceptable, and family of some patients even want to obtain the CCAS that they can play it at home. Generally, the CCAS is potential.

4 Conclusion

Due to the aging problem of our society, it is an important issue to deal with the dementia. If the patients can be diagnosed and treated earlier, not only can slow down the disease degradation, but also can save more labors and cost on caregiving. Nowadays, smart phones and tablet are easily available, so the App-based game assessment is proposed and developed in this paper for early detection. Based on the comparison analysis, the proposed system is demonstrated to be a potential tool for dementia screening.

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